

PATENT APPLICATION

SURFACE MOUNT MULTI-CHANNEL OPTOCOUPLER

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SURFACE MOUNT MULTI-CHANNEL OPTOCOUPLER

BACKGROUND OF THE INVENTION

[0001] Optocouplers contain at least one optical emitter device which is optically coupled to an optical receiver device through an optically transmissive medium. This arrangement permits the passage of information from one electrical circuit that contains the optical emitter device to another electrical circuit that contains the optical receiver device. A high degree of electrical isolation is maintained between the two circuits. Because information is passed optically across an insulating gap, the transfer is one way. For example, the optical receiver device cannot modify the operation of a circuit containing the optical emitter device. This feature is important because, for example, the emitter may be driven by a low voltage circuit using a microprocessor or logic gates, while the output optical receiver device may be part of a high voltage DC or AC load circuit. The optical isolation also prevents damage to the input circuit caused by the relatively hostile output circuit.

[0002] A common optocoupler package format is the dual-in-line package or DIP. This package is widely used to house integrated circuits and is also used for conventional optocouplers. Various versions of optocoupler DIP packages having 4, 6, 8 or 16 pins are commonly manufactured.

[0003] FIG. 1 shows a cross section of a conventional optocoupler DIP package 10. The illustrated optocoupler 10 includes a lead frame 24 comprising leads 24(a), 24(b) (*i.e.*, pins). An optical emitter device 12 is mounted on one lead 24(a). An optical receiver device 14 is mounted on the other lead 24(b). The optical receiver device 14 generates an electrical signal after receiving light generated by the optical emitter device 12. The optical emitter device 12 is electrically coupled to the lead 24(a) through its bottom surface, and to another lead (not shown) via a wire 11. Similarly, optical receiver device 14 is electrically coupled to the lead 24(b) through the bottom surface and to another lead (not shown) via a wire 13. It will be recognized by those skilled in the art that the optical emitter device 12 operates with two electrical connections, an anode and a cathode. These connections are thus provided by the wire 11 and the lead 24(a). Similarly, optical receiver device 14 operates with two electrical connections, typically an emitter and a collector. These connections are provided by the wire 13 and lead 24(b). The optocoupler package 10 further includes an optically

transmissive medium 16. A molding compound 18 encases the leadframe 24, optical emitter device 12, optical receiver device 14, and the optically transmissive medium 16.

[0004] A number of improvements could be made to the optocoupler package 10 shown in FIG. 1. For example, the optocoupler package 10 requires an expensive and time consuming overmolding process. In the overmolding process, the molding compound 18 encapsulates the other parts of the optocoupler package 10. In addition to the overmolding process itself, mold material removal processes (*e.g.*, dejunk and deflash processes) are used to remove excess molding compound, thus adding to the time and expense of forming an optocoupler package. In addition, the tooling that is needed to create moldings of different "form factors" (*e.g.*, 4, 6, or 8 pin packages) requires a significant capital investment. Accordingly, if the overmolding process could be eliminated, the time and costs associated with producing optocoupler packages could be reduced.

[0005] Other improvements to the optocoupler package 10 could also be made. The optocoupler package 10 is also prone to failure from thermal cycling. For example, the difference in the thermal expansion properties of the molding compound 18 and the optically transmissive medium 16 causes them to expand and contract at different rates when they are heated and cooled. The molding compound 18 and the optically transmissive medium 16 could potentially separate, thus resulting in a structurally weak package. Temperature cycling also produces stress at the points where the lead frame 24 exits the molding compound 18 (*e.g.*, at point "A"). The stress can result in a broken or weakened lead frame 24. Also, the wires 11, 13 can sometimes pass through the optically transmissive medium 16 and the molding compound 18. Differences in the thermal expansion properties of the optically transmissive medium 16 and the molding compound 18 can induce stress in the wires 11, 13 and can cause them to break.

[0006] It would also be desirable to reduce the height of conventional optocoupler packages. The optocoupler package 10 shown in FIG. 1 is relatively high. For example, the net height of a typical DIP package is about 3.5 to about 4.0 mm. It would be desirable to reduce the height of the optocoupler package so that it has a lower profile. By doing so, smaller electronic components could be produced.

[0007] It would also be desirable to increase the functionality of the above-described package and also to reduce the costs associated with manufacturing the optocoupler package.

[0008] Embodiments of the invention address these and other problems, individually and collectively.

SUMMARY OF THE INVENTION

[0009] Embodiments of the invention are directed to optocoupler packages and
5 methods for making the same.

[0010] One embodiment of the invention is directed to an optocoupler package comprising: (a) a substrate comprising a leadframe and a molding compound; (b) an optical emitter; (c) an optical receiver, wherein the optical emitter and the optical receiver are electrically coupled to the leadframe; and (d) an optically transmissive medium disposed
10 between the optical emitter and optical receiver.

[0011] Another embodiment of the invention is directed to a method for forming an optocoupler package comprising: (a) forming a substrate comprising a leadframe and a molding compound; (b) attaching an optical emitter and an optical receiver to the substrate; and (c) depositing a light transmissive material between the optical emitter and the optical
15 receiver.

[0012] Another embodiment of the invention is directed to an optocoupler package comprising: (a) a substrate; (b) at least two optical emitters; (c) at least two optical receivers; and (d) optically transmissive media between adjacent optical emitters and optical receivers, wherein the optical emitters and the optical receivers are on the substrate.

[0013] These and other embodiments are described in further detail below.
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BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 shows a prior art optocoupler package.

[0015] FIG. 2 shows a substrate according to an embodiment of the invention from a
25 bottom perspective view.

[0016] FIG. 3 shows the substrate in FIG. 4 showing the internal leadframe configuration.

[0017] FIG. 4 shows a bottom plan view of the substrate shown in FIG. 5.

[0018] FIG. 5 shows a side cross-sectional view of the substrate shown in FIG. 4 along the line A-A.

[0019] FIG. 6 is another bottom plan view of the substrate illustrating different optocoupler quadrants.

5 [0020] FIG. 7 shows an optocoupler package according to an embodiment of the invention from a bottom perspective view.

[0021] FIG. 8 shows an optocoupler package according to an embodiment of the invention from a top perspective view.

10 [0022] FIG. 9 is a bottom perspective view of an optocoupler package from a bottom perspective view, and where optical emitters and optical receivers are shown.

[0023] FIG. 10 is a bottom plan view of an optocoupler package showing optical receivers and optical emitters.

[0024] FIG. 11 shows an optocoupler assembly including an optocoupler package mounted on a substrate.

15 **DETAILED DESCRIPTION**

[0025] In embodiments of the invention, one or more optocouplers are on a single substrate that is formed from a leadframe and a molding compound. For example, there can be four optocouplers in a quad array on a single substrate. Each optocoupler can include an optical emitter (*e.g.*, a light emitting diode) and an optical receiver (*e.g.*, a photodiode). The
20 spacing between the optical receiver and the optical emitter can be from about 0.3 mm to about 0.5 mm. Each optocoupler can be secured with an optically transmissive coupling gel and can be encapsulated with an opaque, highly reflective epoxy based polymer. The functional terminals for the optocouplers can be grouped and routed towards the periphery of the package so that a ball grid array layout is formed. The optical receivers, the optical
25 emitters, and wire bond pads are arranged so that they will correspond to the terminals of the leadframe.

[0026] Logic devices such as control chips can also be on the leadframe-based substrate and may also be in the optocoupler package. Also, chips including MOSFETs

(metal oxide semiconductor field effect transistors) such as power MOSFETs with or without
trenched gates may be on the substrate and in the package. Such chips or devices may be on
the substrate and may be electrically coupled to components such as optical emitters and
optical receivers.

5 **[0027]** In some embodiments, the optocoupler package is a thin and has at least two
optocouplers (*e.g.*, four optocouplers). Advantageously, a single optocoupler package can
provide the same or improved performance as compared to four stand-alone optocoupler
packages with one optocoupler each. As will be shown below, the peripheral solder ball
layout in the package allows for a simpler board design, because the routings of the
10 conductive traces are already integrated into the optocoupler package. This also saves space
on the board to which the optocoupler package is attached.

[0028] FIGS. 2-3 show a pre-molded leadframe substrate **1** that is used in the
optocoupler package. It comprises a leadframe **2** and a molding compound **3**. The leadframe
2 may include a die attach area where two or more dies including optical receivers and optical
15 emitters are placed. Additional chips such as control chips could also be mounted on the
leadframe. Two or more leads may extend from the die attach area and may form terminals
of a leadframe. "Leadframe" includes leadframe structures that may or may not have been
processed (*e.g.*, by etching). In other cases, other types of substrates could be used.

[0029] Referring to FIGS. 4-5, the leadframe **2** is the skeletal framework of the
20 substrate **1**. It has intricate half-etched **2a**, non-etched **2b** and through-hole or fully etched **2c**
patterns in it to define functional pads and locking areas (to lock to the molding compound **3**)
of the substrate **1**.

[0030] The leadframe **2** can comprise any suitable metal and may be of any suitable
thickness. For example, a high mechanical strength copper alloy is preferred. The leadframe
25 **2** can have a thickness of about 0.2 mm (8 mils) or less in the etched or non-etched areas.
Etching processes are known to those of ordinary skill in the art. The leadframe **2** may also
include plating layers such as Ni, Pd, Au or Ag, etc.

[0031] The molding compound **3** of the substrate **1** forms the body of the substrate **1**.
It fills in the through-hole **2c** and half-etched regions **2a** of the leadframe **1**. In this example,
30 the non-etched regions **2b** of the substrate **1** are not covered with the molding compound **3**.

[0032] The molding compound **3** can comprise a polymeric and/or composite material that may or may not require post mold curing. It may contain epoxy resins, hardeners, elastomers, non-phosphorus flame retardants, lubes, silica fillers, etc. It may have balanced particle sizes in it to ensure complete filling of the half-etched regions of the leadframe **2**. It may also contain a sufficient amount of carbon black pigment for better laser marking contrast. The materials making up the balance of the mold compound **3** constituent materials can be used to prevent substrate warpage.

[0033] In some embodiments, the substrate **1** can be formed using tape. For example, tape can be attached to the non-etched pads **2b** of the leadframe **2**, such that the molding compound **3** (or mold bleed or mold flash) does not occupy the functional pads of the substrate **1**. The untaped side of the leadframe **2** is overmolded by approximately 0.1 mm in order to add mechanical strength to the substrate **1**. In other embodiments, no overmolding is present and the molding compound **3** is only within the interstices of the leadframe **2**. The thickness of the substrate **1** can vary depending upon the mechanical and physical requirements of the package **20**.

[0034] As shown in the Figures, the molding compound **3** in the substrate **1** defines the functional pads. These functional pads are the non-etched regions **2b** of the leadframe **2**.

[0035] Additional substrate forming details can be found in U.S. Patent Application No. 10/233,248, filed on August 30, 2002, which is herein incorporated by reference in its entirety.

[0036] Referring to FIG. 6, the optocoupler package may be divided into four quadrants with four optocouplers, Optocouplers I-IV. Optocoupler I occupies quadrant I (**101**). Optocoupler II occupies quadrant II (**102**). Optocoupler III occupies quadrant III (**103**). Optocoupler IV occupies quadrant IV (**104**).

[0037] Referring to both FIGS. 6-7, the functional pads of the substrate **1** can be labeled as follows:

- a) the four inner assembly pads of Optocoupler I **21** are Cathode I (or diode die attach pad I) **4a**, Anode I (or diode weld pad I) **5a**, Collector I (or phototransistor die attach pad I) **6a** and Emitter I (or phototransistor weld pad I) **7a**;

- b) the four inner assembly pads of Optocoupler II **22** are Cathode II (or diode die attach pad I) **4b**, Anode II (or diode weld pad II) **5b**, Collector II (or phototransistor die attach pad II) **6b** and Emitter II (or phototransistor weld pad II) **7b**;
- c) the four inner assembly pads of Optocoupler III **23** are Cathode III **4c**, Anode III **5c**,
5 Collector III **6c** and Emitter III **7c**; and
- d) the four inner assembly pads of Optocoupler IV **24** are Cathode IV **4d**, Anode IV **5d**,
Collector IV **6d** and Emitter IV **7d**.

[0038] The non-etched functional pads of the substrate **1** are connected to the terminal pads for peripheral solder ball attachment. These are grouped and routed to make up a
10 symmetrical package substrate **1** with common terminal pads. The peripheral ball attach pads are labeled as follows:

- e) cathode or diode die attach pads of Optocouplers I and IV (**4a**, **4d**) are shorted and connected to a common cathode terminal pad **8a** and is situated at the outer boundary of quadrants I and IV;
- 15 f) cathode or diode die attach weld pads of Optocouplers II and III (**4b**, **4c**) are shorted and connected to a common cathode terminal pad **8b** and is situated at the outer boundary of quadrants II and III;
- g) each of the anode terminal pads **9a**, **9b**, **9c**, **9d** of all optocouplers are situated independently at the peripheral corner of each quadrant;
- 20 h) collector terminal pads **10a**, **10b**, **10c**, **10d** of each optocoupler are independently and laterally situated directly opposite the anode terminal pads;
- i) emitter or phototransistor weld pads **7a**, **7b**, **7c**, **7d** of all optocouplers are shorted and routed towards the central horizontal periphery of the substrate resulting in two symmetrical peripheral terminal pads **11** for the emitter solder balls. The anode-cathode
25 pads keep about a 0.5 mm gap with the emitter-collector pads in all optocouplers. This will ensure a high voltage breakdown for each optocoupler.

[0039] FIG. 7 shows an optocoupler package **20** containing four optocouplers including glob-topped domes **21**, **22**, **23**, **24**. The glob top material does not contact the ball attach peripheral terminal pads **8a-8b**, **9a-9d**, **10a-10d** (shown in FIG. 6).

[0040] The optocoupler package **20** includes external peripheral solder balls **25** that are attached to the substrate **1**. Peripheral balls **25** are attached to terminal pads **8a-8b**, **9a-9d**, **10a-10d**, **11**. These balls **25** serve as the immediate connection mechanism for the

optocoupler package **20** to a printed circuit board (PCB) **31** (see FIG. 11). The solder balls **25** preferably include Pb-free alloys with high melting temperatures.

[0041] As shown in FIG. 7, in the illustrated example, the optocoupler package **20** has 12 equally spaced peripheral solder balls **25**. The package peripheral ball out configuration may be changed (based on the same concept of inner assembly pads shorting and terminal routing) depending the specific package pin-out requirements and dies. Although solder balls are described in detail, other conductive structures such as copper columns (*e.g.*, preformed or electroplated) could be used instead. The conductive structures have heights greater than the heights of the optical receivers and the optical emitters in the optical package so that flip chip mounting can take place.

[0042] Referring to FIGS. 9 and 10, LED die **26** generates photons when a forward current is applied to the optocoupler, resulting to light emissions from the P-N junction in the die **26**. An LED die having a height of about 9 mils or below can be used.

[0043] Phototransistor die **27** detects light emitted by the LED die **26** and converts it to electrons resulting in current flow at the optocoupler output. Light detection happens at its collector-base junction. A phototransistor die height of about 8 mils or below can be used.

[0044] Referring to FIGS. 6, 9, and 10, a die attach material (not shown) bonds the back of each LED die **26** to its designated die attach pad **4a**, **4b**, **4c**, **4d**. Similarly, it bonds the back of each phototransistor die **27** to its designated die attach pad **6a**, **6b**, **6c**, **6d**. The die attach material can be any conductive bonding material. Examples include Ag-filled epoxies, soft solders, etc. In some embodiments, a die attach fillet can be used and can be controlled at a maximum of about 50% of the die height to maximize light emission from the sides of the LED die **26**.

[0045] Bonding wires **28** connect the anode pad of the LED dies **26** to the diode weld pads **5a**, **5b**, **5c**, **5d** completing the circuitry of the diode components of the package **20**. Similarly, they connect the phototransistor dies **27** to their designated weld pads **7a**, **7b**, **7c**, **7d**. The bonding wires **28** can comprise any suitable ductile metal – Au, Cu, Al, or doped versions of these metals, alloys of these metals, etc. A wire loop is recommended at approximately 14 mils from the substrate.

[0046] The wire bonded LED die and phototransistor die assemblies are coupled together using a light transmissive clear gel material **29**. The optical transparency of the coupling gel **29** allows efficient transfer of the light emitted from the LED **26** junction towards the photosensitive junction of the phototransistor **27**. The coupling gel **29** covers the entire wire bonded die assemblies and forms a near hemispherical dome for maximum transmission of emitted light.

[0047] The light transmissive hemispherical dome **29** of each of the wire bonded LED and phototransistor assemblies is covered with a white reflective glob top material **30** to complete one optocoupler internal package structure. Glob top **30** (or light reflective material) is a light reflective material that keeps the emitted light within the confines of the dome. The glob top coating conforms to the dome shape and can totally cover the clear coupling gel **29** (or light transmissive material). It seals the dome by adhesion. The glob top material **30** can have a minimum thickness of about 0.2 mm.

[0048] The optocoupler package can be manufactured according to the following steps.

[0049] First, a leadframe molding process can be performed. A leadframe molding process is performed using a taped leadframe as described above. A piece of tape can be attached to the non-etched pads of a leadframe, such that molding compound does not occupy the functional pads of the subsequently formed substrate. The untaped side of the leadframe is overmolded to add mechanical strength to the substrate.

[0050] Second, a die attach process can be performed. For example, LED and phototransistor dies can be attached using an adhesive with a conductive filling or solder. Die attach curing may or may not be necessary depending on the type of adhesive used.

[0051] Third, a wire bond process can be performed to form conductive paths between the dies and their corresponding pads in the substrate. For example, a thermosonic or ultrasonic wirebonding process can be performed in some embodiments.

[0052] Fourth, a dome coat and cure process can be performed. Any suitable liquid dispensing process can be used to dispense the clear coupling gel to form the light transmissive hemispherical dome. Curing may be needed to improve the physical characteristics of coupling gel. Suitable dome coat materials include silicone based materials

that are available from Dow Corning and General Electric, although any suitable vendor may be used.

[0053] Fifth, a glob top and cure process can be performed. Any suitable liquid dispensing process can be employed for opaque glob topping. Curing may or may not be needed depending on the type of material used. Suitable reflective coating materials include epoxy based coatings with reflective pigments based on materials such as titanium dioxide or other metal oxides. They are commercially available from from Epotek and Hysol, although any suitable vendor may be used.

[0054] Sixth, a solder deposit process can be performed (*e.g.*, for solder balls 25 in the Figures). Solder ball attach, fluxing, ball placement or ball shooting, ball jetting and other processes can be employed to attach conductive structures such as solder to the substrate. In other embodiments, conductive columns (*e.g.*, copper columns) could be placed on the substrate instead, or could be electroplated on the substrate.

[0055] Seventh, a solder reflow process can be performed (if solder is used). Convection or conduction or radiation solder reflow processes can be used in some embodiments.

[0056] Eighth, a singulation process can be performed. Singulation processes include blade sawing, water jet sawing, laser sawing and the like. Singulation processes separate the formed substrates from each other.

[0057] Ninth, electrical testing can be performed. High-voltage testing and parametric testing can be used to exclude any packages with electrical defects.

[0058] Tenth, a package marking process can be performed. Laser or pad marking or other process can be used to provide package identification and orientation.

[0059] After a package is formed, it can be flipped over and mounted onto a printed circuit board as shown in FIG. 11. Common surface assembly techniques can be used.

[0060] It is noted that the above described processes can be performed in the order described above, or they can be performed in a different order.

[0061] It is noted that the present invention is not limited to the preferred embodiments described above, and it is apparent that variations and modifications by those skilled in the art can be performed within the spirit and scope of the present invention. Moreover, any one or more embodiment of the invention may be combined with one or more
5 embodiments of the invention without departing from the spirit and scope of the invention.

[0062] All U.S. provisional and non-provisional patent applications and publications mentioned above are incorporated by reference in their entirety for all purposes. None is admitted to be prior art.